Short-term Planning, Monetary Policy, and Macroeconomic Persistence

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Motivation: Behavioral Macro Models

- Recent **behavioral macro models** emphasize that agents' expectations can be rooted in human judgement and experimental evidence instead of being assumed fully-rational.
  - *Gabaix's (2018)* limited attention model.
  - *Angeletos and Lian's (2016)* lack of common knowledge.
  - *Farhi and Werning's (2017)* k-level thinking.
  - *Woodford's (2018)* finite planning horizons (FH).

- **Do "new behavioral" models provide empirically-realistic macro dynamic to study the effects of monetary policy?**

Motivation: Macroeconomic Persistence

"The pervasiveness of sluggish responses in the macro data, combined with the implausibility of many of the micro stories underlying adjustment cost models, suggests that we look for a different approach to modeling the sources of inertia in both prices and real variables."

Sims (1998), Stickiness.

Plan of the Presentation

- **Heuristic** description of finite-horizon planning.
- **Preview** of the results.
- **Formal** representation of the *aggregate equilibrium*.
  - Microeconomic heterogeneity.
  - Value function updating and *trend-cycle* decomposition.
  - Short-term planning and monetary policy.
    - A new trend-cycle decomposition.
    - A (modified) Taylor principle.
- **Estimation results.**
  - Two key parameters.
  - Trend-cycle decomposition of US output, inflation, and short-term rate.
  - Individual heterogeneity: *disagreement of expectations*.

Finite-Horizon Planning: Heuristic

Finite-Horizon (FH) Planning

- The **backbone** of the model **is NK**.
- Agents make **plans over a finite horizon (FH):**
  - Too costly to search all possible decision tree (infinite-horizon state-contingent plan, "Borges' *garden of forking paths*")
  - They transform an infinite-horizon problem into a sequence of shorter finite-horizon ones (finite future.)
  - They are "boundedly rational" in thinking about the continuation values of their plans.
  - They (learn) update their beliefs on the continuation values of their plans based on past data/experience.
- Agents are **forward-looking** in thinking about events *over* their planning horizon, but **are also backward looking** in thinking about events *beyond* that point.
- **HANK: Rich cross-sectional heterogeneity in the length of planning horizons**.

K-Horizon Plan: Time Diagram

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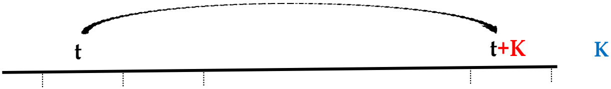

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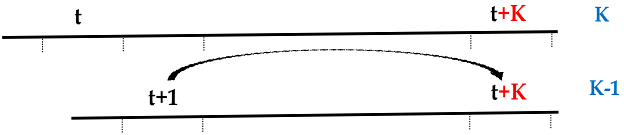

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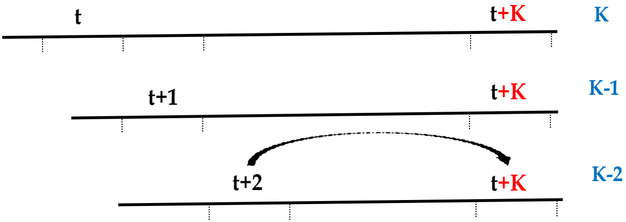

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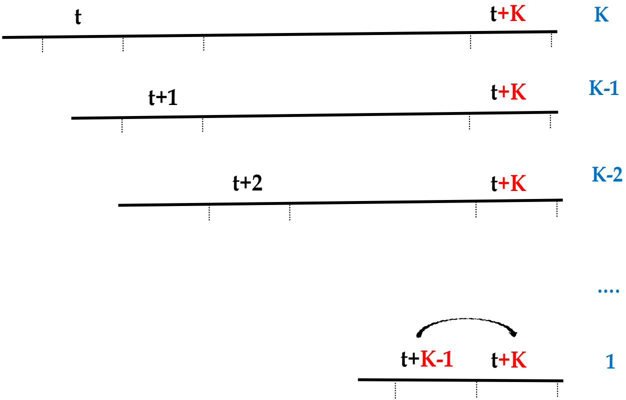

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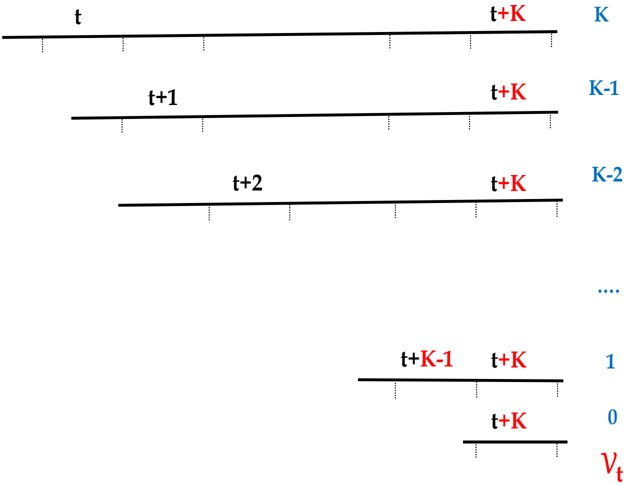

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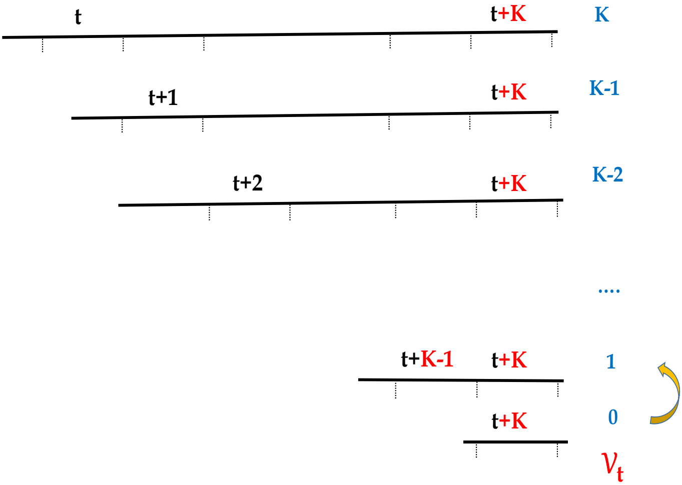
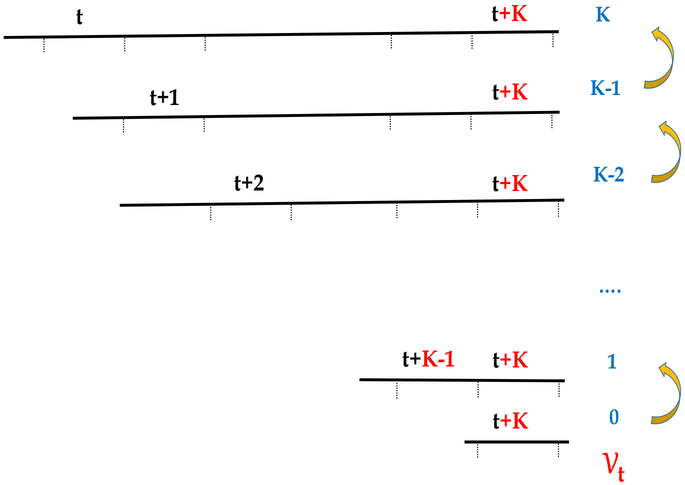


K-Horizon Plan: Time Diagram



Macroeconomic Persistence

The **model generates persistence** through a novel "trend-cycle decomposition."

- The **"cyclical component"** depends on agents' forward looking behavior over their planning period (i.e., absent learning).
- The **"trend component"** reflects how agents update beliefs about their continuation plans (i.e., value functions) to past information.
  - Without habits in consumption, indexation clauses, and interest-rate smoothing.
  - Without purely "backward-looking expectations."

Preview of the Results

Preview of the Results (1/2)

- We estimate the FH model using **U.S. quarterly data on output, inflation, and interest rates from 1966 until 2007.**
  - About 50 percent of agents plans for the current-quarter, and a small fraction have planning horizons beyond 2yrs.
  - Agents update their value functions slowly in response to incoming data.
- **Model goodness of fit is substantially better than:**
  - The hybrid-NK model and other behavioral macro models (such as *Angeletos and Lian's (2016)* and *Gabaix's (2018)* .)

Preview of the Results (2/2)

- Model generates **"substantial persistence"** in output, inflation, and interest rates.
    - Without any of the usual mechanisms and without "interest-rate smoothing."
- Business cycle matches **"conventional wisdom."**
- Measure of **trend inflation** displays similar movements to the SPF measure of longer-term inflation expectations.
- **"Disagreement about inflation expectations"** due to agents' heterogeneous plans matches the contour derived from the Michigan Survey.

The Formal Model

Households K-Horizon Planning

- HH problem in t is to choose state-contingent plan $C_\tau(s_\tau)$ for periods $t \leq \tau \leq t+k$ to maximize:

$$\mathbb{E}_t^k \left[\sum_{\tau=t}^{t+k} \beta^{\tau-t} u(C_\tau, \xi_\tau) + \beta^{k+1} \vartheta(B_{t+k+1}, s_{t+k}) \right]$$

subject to the budget constraint

$$B_{\tau+1} = (1+i_\tau)[B_{\tau+1}/\Pi_\tau + Y_\tau - C_\tau]$$

- The nominal value of government debt maturing in period τ is deflated by the aggregate price level $P_{\tau-1}$.
- $\vartheta(B_{\tau+1}, s_\tau)$ is the value function used by the HH to evaluate situations in final state τ.
- $\mathbb{E}_t^k[\cdot]$ is the expectation at time t for agents with k forward planning horizon.

Households K-Horizon Planning

- **Optimal plan** for $t \leq \tau \leq t+k$

$$\begin{aligned} u_c(C_\tau, \xi_\tau) &= \beta \mathbb{E}_t^k \left[\frac{(1+i_\tau)}{\Pi_{\tau+1}} u_c(C_{\tau+1}, \xi_{\tau+1}) | s_\tau \right] \text{ and} \\ u_c(C_{t+k}, \xi_{t+k}) &= \beta(1+i_{t+k}) \vartheta_B(B_{t+k+1}, s_{t+k}) \end{aligned}$$

- **Expectations** in $t \leq \tau \leq t+k$ used in planning:
  - Understand the model structure during the planning.
  - For any j periods between t and $t+k$, aggregate conditions in $t+j$ assumed to be determined by $k-j$ horizon forward looking HHs

$$\begin{aligned} t &\leq \tau \leq t+k: & \mathbb{E}_t^k\{Z_\tau | s_\tau\} = E_t\{Z_\tau^{t+k-\tau}\} \\ t+1 &\leq \tau \leq t+k: & \mathbb{E}_t^k\{Z_{\tau+1} | s_\tau\} = E_\tau\{Z_{\tau+1}^{t+k-\tau}\} \end{aligned}$$

- Assume the same planning horizon for all others.

Households K-Horizon Planning

- **Optimal plan** for $t \leq \tau \leq t+k$ and $1 \leq j \leq k$ the intertermporal decision is given by:

$$
\begin{aligned}
u_c(C_\tau^j, \xi_\tau) &= \beta E_\tau \left[\frac{(1+i_\tau^j)}{\Pi_{\tau+1}^{j-1}} u_c(C_{\tau+1}^{j-1}, \xi_{\tau+1}) \right] \\
u_c(C_\tau^0, \xi_\tau) &= \beta(1+i_\tau)\vartheta_B(B_{\tau+1}^0; s_\tau)
\end{aligned}
$$

- **Log-linear approx.** (constant $\vartheta(B) = \frac{u(C,\xi)}{1-\beta}$; $Y = C$):

$$
\begin{aligned}
\widetilde{y}_t^j - \xi_t &= E_t[\widetilde{y}_{t+1}^{j-1} - \xi_{t+1}] - \sigma(\widetilde{i}_t^j - E_t \widetilde{\pi}_{t+1}^{j-1}), \; 1 \leq j \leq k \\
\widetilde{y}_t^0 - \xi_t &= -\sigma \widetilde{i}_t^0, \; j = 0
\end{aligned}
$$

- HHs solve this plan at t by **backward induction from** $t+k$.

Firms K-Horizon Planning

- **Firms choose P_t^f of good f to maximize:**

$$\mathbb{E}_t^f \left[\sum_{\tau=t}^{t+k} (\alpha\beta)^{\tau-t} \lambda_\tau \wp^f(\widetilde{p}_t^f, A_\tau) + (\alpha\beta)^{k+1} \vartheta^f(\widetilde{p}_{t+k}^f) \right]$$

where $\widetilde{p}_t^f = \frac{P_t^f \Pi^{\tau-t}}{P_\tau}$.

- **Optimal plan**:

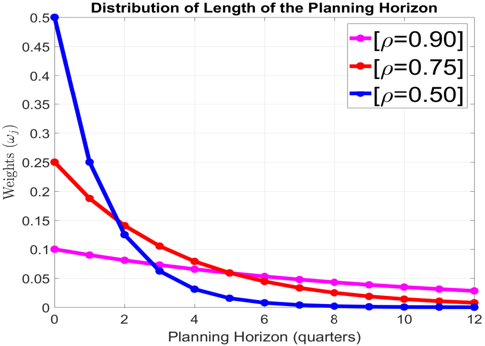
$$\mathbb{E}_t^f \left[\sum_{\tau=t}^{t+k} (\alpha\beta)^{\tau-t} \lambda_\tau \wp_{\widetilde{p}}^f(\widetilde{p}_t^f, A_\tau) \frac{P_t^f \Pi^{\tau-t}}{P_\tau} + (\alpha\beta)^{k+1} \vartheta_{\widetilde{p}}^f(\widetilde{p}_{t+k}^f) \frac{P_t^f \Pi^k}{P_{t+k}} \right] = 0$$

- **Log-linear approximation** (contant $\vartheta^f(\widetilde{p}^f) = \frac{\lambda \wp^f(\widetilde{p}^f)}{1-\alpha\beta}$):

$$\begin{aligned} \widetilde{\pi}_t^j &= \beta E_t[\widetilde{\pi}_{t+1}^{j-1}] + \kappa(\widetilde{y}_t^j + \xi_t - y_t^*),\ 1 \le j \le k \\ \widetilde{\pi}_t^0 &= \kappa(\widetilde{y}_t^0 + \xi_t - y_t^*),\ j = 0 \end{aligned}$$

Heterogeneous Planning and Aggregation

- Let ω_j be the **fraction of HHs (and Fs) with planning horizon** j ($\forall\ j = 0, 1, 2, ...$). Such that $\sum_j \omega_j = 1$.
- **Exponential Distribution:** $\omega_j = (1-\rho)\rho^j$, $0 < \rho < 1$



- **Aggregates**:

$$\widetilde{y}_t = (1-\rho)\sum \rho^j \widetilde{y}_t^j \qquad \widetilde{\pi}_t = (1-\rho)\sum \rho^j \widetilde{\pi}_t^j$$

Cyclical Dynamics (Constant Value Functions)

- **NK-FH model (cycle):**

$$
\begin{aligned}
\widetilde{y}_t &= \rho E_t[\widetilde{y}_{t+1}] - \sigma\left[\widetilde{i}_t - \rho E_t(\widetilde{\pi}_{t+1})\right] \\
\widetilde{\pi}_t &= \beta\rho E_t[\widetilde{\pi}_{t+1}] + \kappa\widetilde{y}_t + \kappa(\xi_t - y_t^*) \\
\widetilde{i}_t &= i_t^* + \phi_\pi\widetilde{\pi}_t + \phi_y\widetilde{y}_t
\end{aligned}
$$

  and the baseline NK model if $\rho \to 1$.

- **In a more compact form:**

$$\widetilde{x}_t = \rho M\ E_t\{\widetilde{x}_{t+1}\} + Nu_t$$

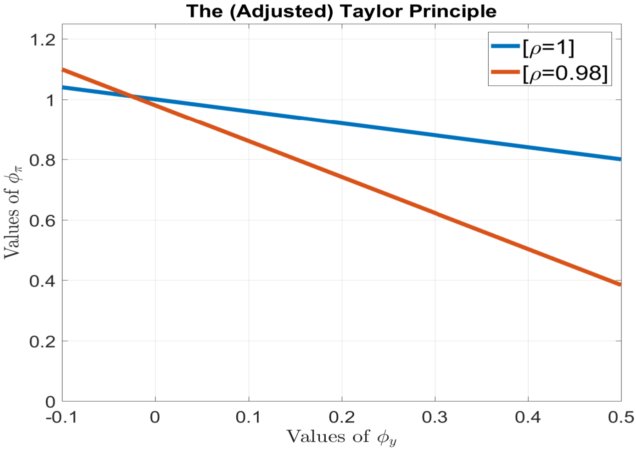
  where $\widetilde{x}_t = (\widetilde{y}_t, \widetilde{\pi}_t)'$.

$$M = \frac{1}{\delta}\begin{pmatrix} 1 & \sigma(1-\beta\phi_\pi) \\ \kappa & \kappa\sigma + \beta(1+\sigma\phi_y) \end{pmatrix}$$

$\delta = 1 + \sigma(\phi_y + \kappa\phi_\pi)$.

Modified Taylor Principle

$$\frac{1-\rho\beta}{\kappa}\phi_y + \phi_\pi > \rho$$



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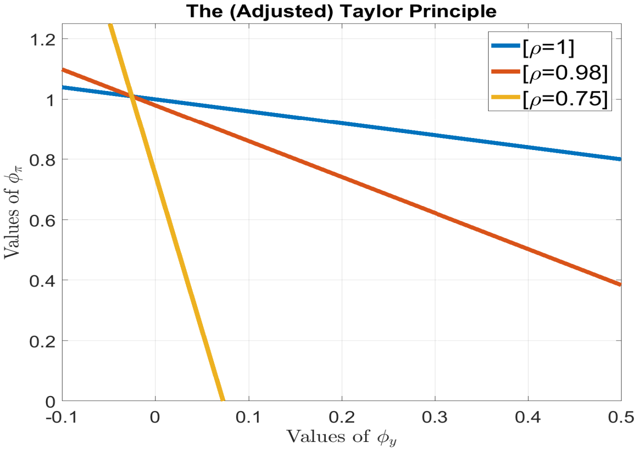


Trend Component and Value Function Updating

- Updating the value function leads to changes in trends:

$$
\begin{aligned}
\widetilde{y}_t &= y_t - \xi_t - \overline{y}_t = (1-\rho)\sum_j \rho^j (y_t^j - \overline{y}_t^j) - \xi_t \\
\widetilde{\pi}_t &= \pi_t - \overline{\pi}_t = (1-\rho)\sum_j \rho^j (\pi_t^j - \overline{\pi}_t^j) \\
\widetilde{i}_t &= i_t - \overline{i}_t = (1-\rho)\sum_j \rho^j (i_t^j - \overline{i}_t^j)
\end{aligned}
$$

- Without updating the value functions: $\overline{y}_t = \overline{\pi}_t = \overline{i}_t = 0$.

Trend Component and Value Function Updating

- Time-varying trends arise from adjustment in agents' beliefs about the continuation values of their plans.
- The zero (last bit of planning) condition depends upon the aggregate value functions of households (ν_t) and firms ($\widetilde{\nu}_t$):

$$\begin{aligned} \overline{y}^0_{t+k} &= -\sigma \bar{i}^0_{t+k} + \nu_t \\ \overline{\pi}^0_{t+k} &= \kappa \overline{y}^0_{t+k} + (1-\alpha)\beta\widetilde{\nu}_t \end{aligned}$$

- For any planning horizon $j \geq 1$ and any date between t and $t+j$, updating (shooting backward algorithm):

$$\overline{y}^j_{t+j} = \overline{y}^{j-1}_{t+j} - \sigma[\bar{i}^j_{t+j} - \overline{\pi}^{j-1}_{t+j}] \text{ and } \overline{\pi}^j_{t+j} = \beta\overline{\pi}^{j-1}_{t+j} + \kappa\overline{y}^j_{t+j}$$

- How do the value functions evolve? Agent's learning.

Value Function Updating: Learning

- **Constant-gain learning for HHs and Firms:**

$$\begin{aligned} \nu_{t+1} &= (1-\gamma)\nu_t + \gamma \nu_t^{est} \\ \widetilde{\nu}_{t+1} &= (1-\widetilde{\gamma})\widetilde{\nu}_t + \widetilde{\gamma}\widetilde{\nu}_t^{est} \end{aligned}$$

The **parameters** γ and $\widetilde{\gamma}$ are the constant (learning) gains.

- ν_t^{est} and $\widetilde{\nu}_t^{est}$ are the estimated value functions from period-t decision.
- The **continuation values** depend upon (a coarse description of states) aggregate information acquired at time t

$$\begin{aligned} \nu_t^{est} &= y_t - \xi_t + \sigma \pi_t \\ \widetilde{\nu}_t^{est} &= (1-\alpha)^{-1} \pi_t \end{aligned}$$

Monetary Policy

- **Systematic response to cyclical components**

$$\tilde{i}_t = i_t^* + \phi_\pi \tilde{\pi}_t + \phi_y \tilde{y}_t$$

- **Response to trends (time-varying intercept):**

$$\bar{i}_t = \overline{\phi}_y \overline{y}_t + \overline{\phi}_\pi \overline{\pi}_t$$

with $\overline{\phi}_y \geq 0$, $\overline{\phi}_\pi \geq 0$.

- **Testable implications:** $\phi_y = \overline{\phi}_y$ and $\phi_\pi = \overline{\phi}_\pi$.

$$i_t = \bar{i}_t + \phi_\pi \tilde{\pi}_t + \phi_y \tilde{y}_t + i_t^*$$

or

$$i_t = \phi_\pi \pi_t + \phi_y y_t + i_t^*$$

Aggregate Equilibrium Dynamics

- **Aggregate dynamics with learning:**

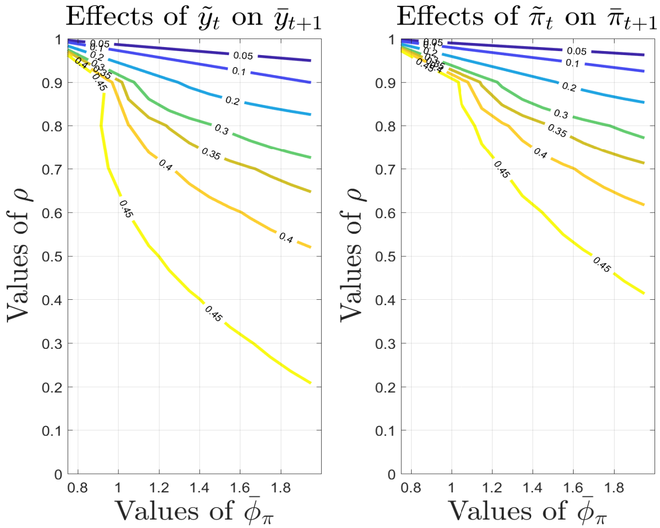
$$\begin{aligned} \widetilde{x}_t &= \rho M \; E_t\{\widetilde{x}_{t+1}\} + N \; u_t \\ \overline{x}_t &= F \; \overline{x}_{t-1} + (1-\rho)\gamma Q \; \widetilde{x}_{t-1} \\ \widetilde{x}_t &= x_t - \overline{x}_t \end{aligned}$$

Assuming $\gamma = \widetilde{\gamma}$, then Q becomes:

$$Q = \frac{1}{\Delta} \begin{pmatrix} 1-\beta\rho & \sigma(1-\beta\overline{\phi}_\pi) \\ \kappa & \kappa\sigma + (1-\rho+\sigma\overline{\phi}_y)\beta \end{pmatrix}$$

with $\Delta = (1-\beta\rho)(1-\rho+\sigma\overline{\phi}_y) + \kappa\sigma(\overline{\phi}_\pi - \rho)$.

Monetary Policy and the Passthrough from Cycle to Trend



Estimation Using Aggregate Data

Data and Estimation

- Estimate the model over **sample 1966:Q1–2007:Q4**, with **three observables**:

$$
\begin{aligned}
\text{Output Growth}_t &= \mu^Q + y_t - y_{t-1} \\
\text{Inflation}_t &= \pi^A + 4\pi_t \\
\text{Interest Rate}_t &= \pi^A + r^A + 4i_t
\end{aligned}
$$

- Period with **notable low-frequency variation** in these time series.
- We allow for **three – AR(1) – shocks**: Technology, Preferences, Monetary Policy.
- We estimate the vector of parameters of the model, θ, using **Bayesian techniques.**

Key Parameters of the Estimated Models

Model Type	**Parameters**		
	Estimated	**Fixed**	**Not Identified**
Forward	ϕ_π, ϕ_y	$\rho = 1$	$\gamma, \widetilde{\gamma}, \overline{\phi}_\pi, \overline{\phi}_y$
Stat. Trends	AR(1) trends	$\rho = 1$	$\gamma, \widetilde{\gamma}, \overline{\phi}_\pi, \overline{\phi}_y$
FH Baseline	$\rho, \gamma, \phi_\pi, \phi_y$	$\phi = \overline{\phi}, \gamma = \widetilde{\gamma}$	-
FH–$\widetilde{\gamma}$	$\rho, \gamma, \widetilde{\gamma}, \phi_\pi, \phi_y$	$\phi = \overline{\phi}$	-
FH–$\overline{\phi}$	$\rho, \gamma, \phi_\pi, \phi_y, \overline{\phi}_\pi, \overline{\phi}_y$	$\gamma = \widetilde{\gamma}$	-

Key Parameters of the Estimated Models

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Forward	ϕ_π, ϕ_y	$\rho = 1$	$\gamma, \widetilde{\gamma}, \overline{\phi}_\pi, \overline{\phi}_y$
Stat. Trends	AR(1) trends	$\rho = 1$	$\gamma, \widetilde{\gamma}, \overline{\phi}_\pi, \overline{\phi}_y$
FH Baseline	$\rho, \gamma, \phi_\pi, \phi_y$	$\phi = \overline{\phi}, \gamma = \widetilde{\gamma}$	-
FH–$\widetilde{\gamma}$	$\rho, \gamma, \widetilde{\gamma}, \phi_\pi, \phi_y$	$\phi = \overline{\phi}$	-
FH–$\overline{\phi}$	$\rho, \gamma, \phi_\pi, \phi_y, \overline{\phi}_\pi, \overline{\phi}_y$	$\gamma = \widetilde{\gamma}$	-

Selected Parameter Estimates: Posterior Distributions

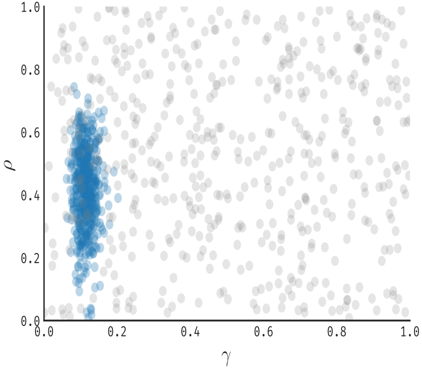
	Forward	**St.Trends**	**FH Base**	**FH–$\overline{\phi}$**	**FH–$\widetilde{\gamma}$**
ρ	-	-			
γ	-	-			
$\widetilde{\gamma}$	-	-			
ϕ_π	1.54 (0.24)	1.49 (0.21)			
ϕ_y	0.92 (0.17)	0.86 (0.19)			
$\overline{\phi}_\pi$					
$\overline{\phi}_y$					
log MDD	-758.20 (1.22)	-718.63 (2.16)			

Selected Parameter Estimates: Posterior Distributions

	Forward	**St. Trends**	**FH Base**	**FH–$\overline{\phi}$**	**FH–$\widetilde{\gamma}$**
ρ	-	-	0.50 (0.13)	0.42 (0.13)	0.46 (0.13)
γ	-	-	0.13 (0.03)	0.11 (0.02)	0.09 (0.05)
$\widetilde{\gamma}$	-	-	-	-	0.17 (0.06)
ϕ_π	1.54 (0.24)	1.49 (0.21)	1.08 (0.13)	0.96 (0.15)	1.10 (0.14)
ϕ_y	0.92 (0.17)	0.86 (0.19)	0.78 (0.16)	0.73 (0.15)	0.77 (0.16)
$\overline{\phi}_\pi$			-	2.03 (0.26)	-
$\overline{\phi}_y$	-	-	-	0.06 (0.06)	-
log MDD	-758.20 (1.22)	-718.63 (2.16)	-727.01 (0.94)	-716.54 (1.34)	-728.27 (1.19)

Model Fit

- Joint posterior dist. of ρ and γ



Model Fit

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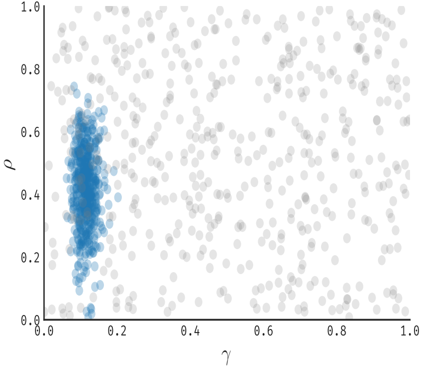
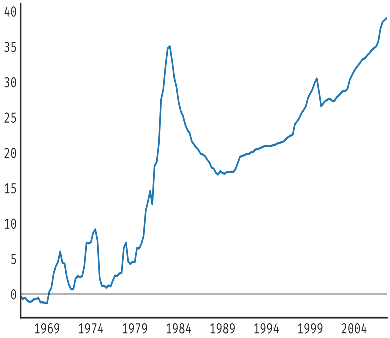


- $\Delta_t = \log \frac{\widehat{p}_{FH-\overline{\phi}}(Y_{1:t})}{\widehat{p}_{Forward}(Y_{1:t})}$



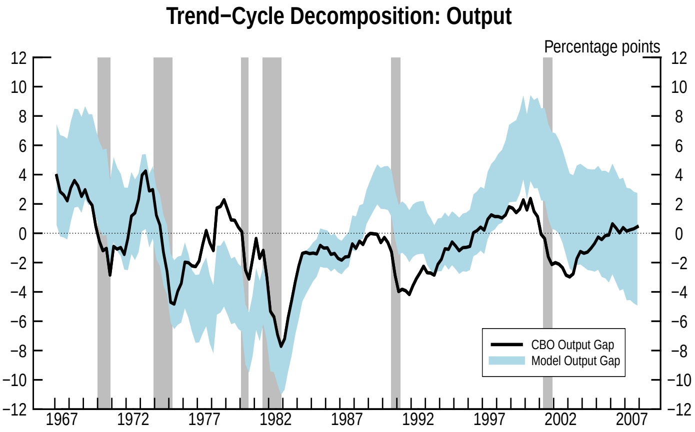
Ranking Overall Fit Alternative Models

$$
\begin{aligned}
\widetilde{y}_t &= \rho E_t\{\widetilde{y}_{t+1}\} - \sigma[\widetilde{i}_t - \lambda E_t\{\widetilde{y}_{t+1}\} - r_t^n] \\
\widetilde{\pi}_t &= \beta \rho_f E_t\{\widetilde{\pi}_{t+1}\} + \kappa \widetilde{y}_t + u_t \\
\widetilde{i}_t &= \phi_\pi \widetilde{\pi}_t + \phi_y \widetilde{y}_t + i_t^*
\end{aligned}
$$

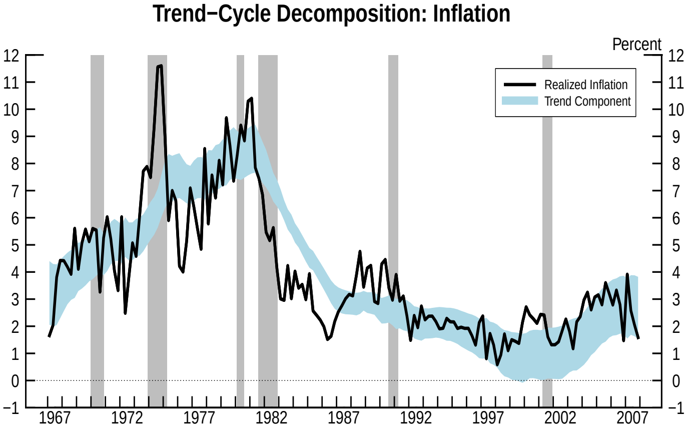
Model	**Log MDD**	
Type	**Mean**	**Std.**
FH–$\overline{\phi}$	-716.54	1.34
Stat. Trends	-718.63	2.16
FH Baseline	-727.01	0.94
FH–$\widetilde{\gamma}$	-728.27	1.19
Angeletos/Lian/Gabaix	-737.00	0.95
Hybrid NK	-734.24	1.55
Forward	-758.20	1.22

Aggregate Implications: Trend vs. Cycle

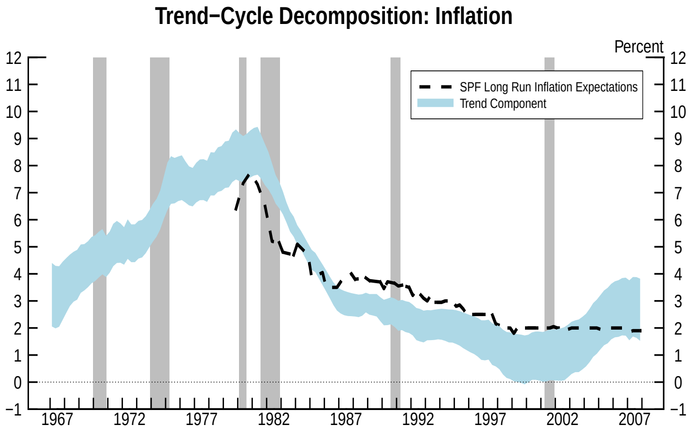
Trend-Cycle Decomposition: Output



Trend-Cycle Decomposition: Inflation

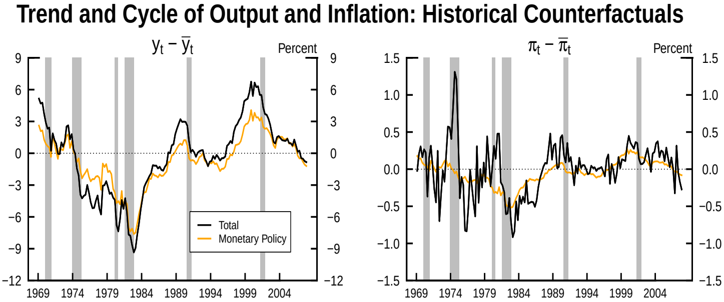


Trend-Cycle Decomposition: Inflation Expectations (SPF)

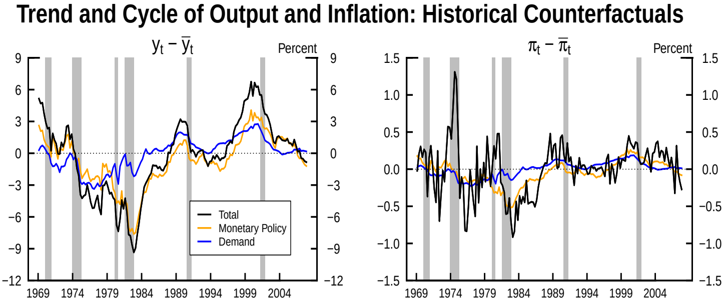


Aggregate Implications: Sources of Business Cycle

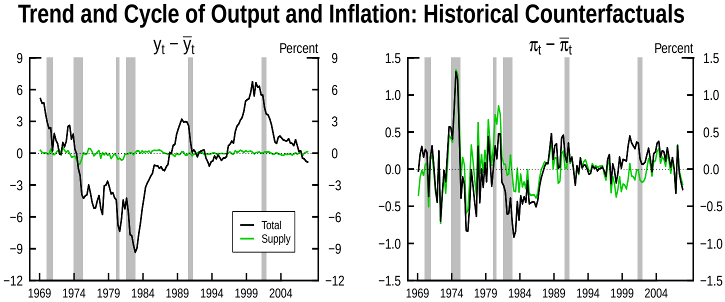
Historical Counterfactuals: Monetary Policy



Historical Counterfactuals: Aggregate Demand

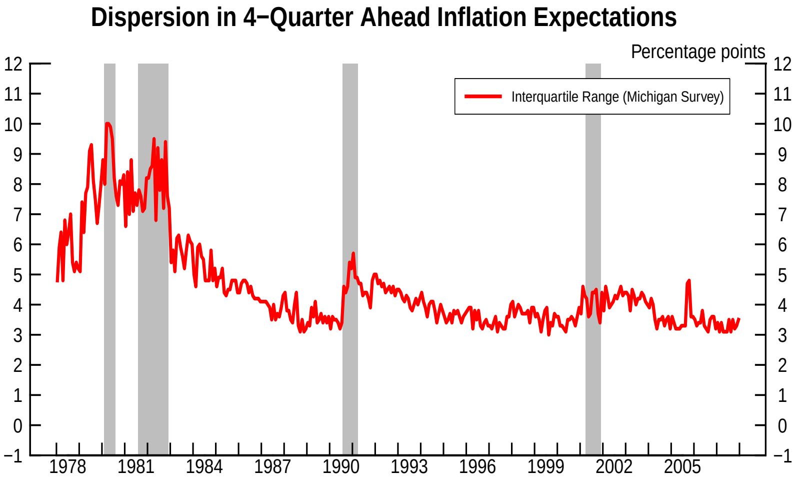


Historical Counterfactuals: Aggregate Demand

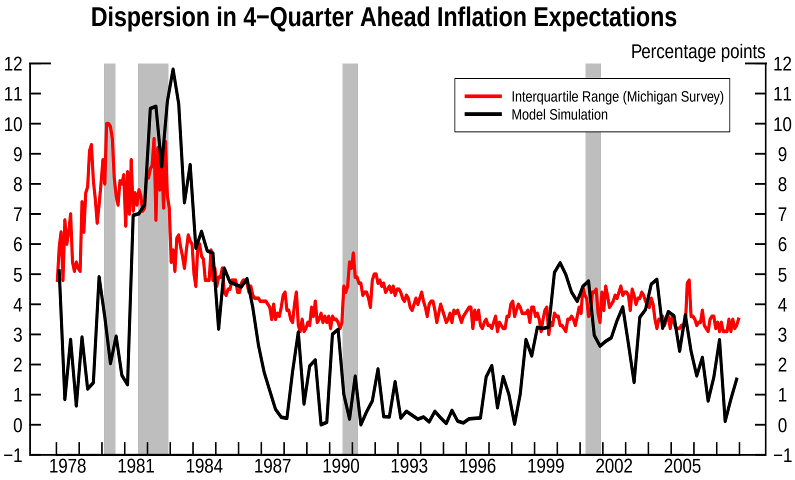


Microeconomic Heterogeneity: Disagreement

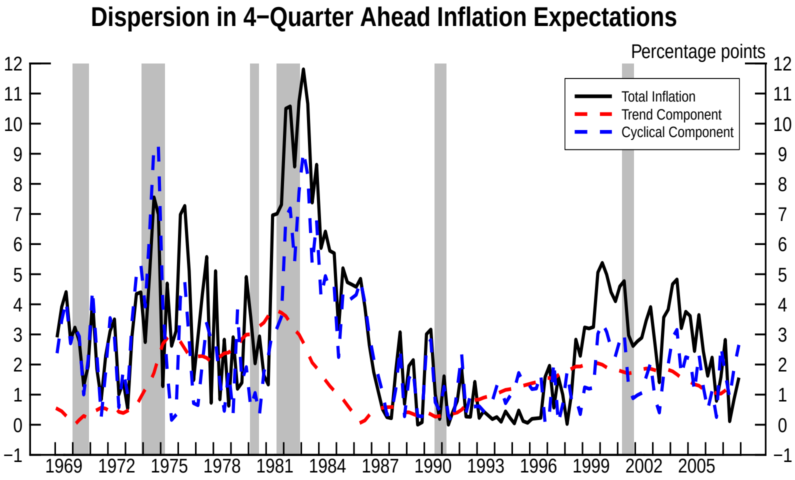
Disagreement about Inflation Expectations (MRW, 2003)



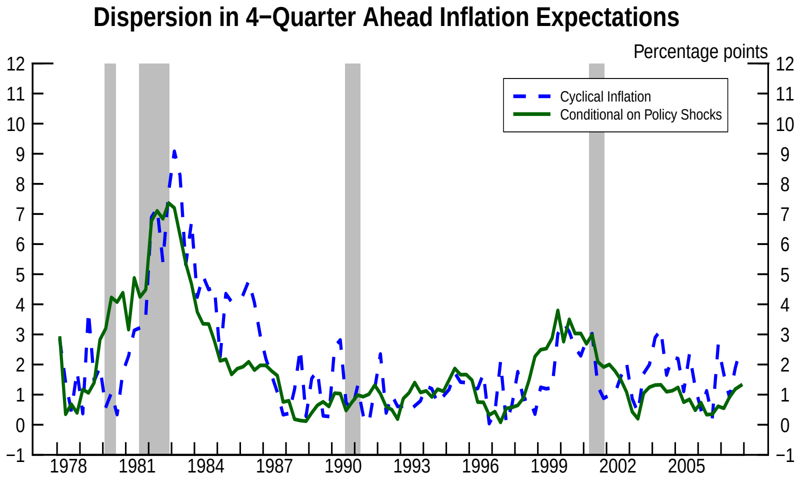
Disagreement about Inflation Expectations (MRW, 2003)



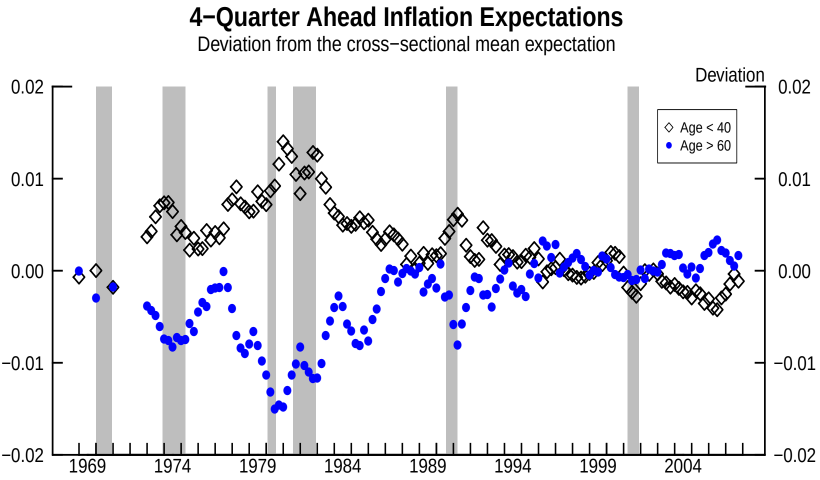
Disagreement about Inflation Expectations (MRW, 2003)



Disagreement about Inflation Expectations (MRW, 2003)

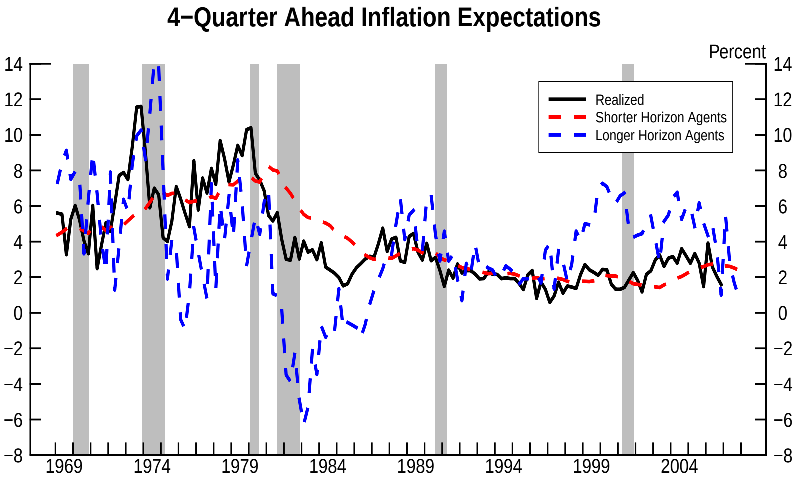


Inflation Experiences (Malmendier-Nagel, QJE 2016)

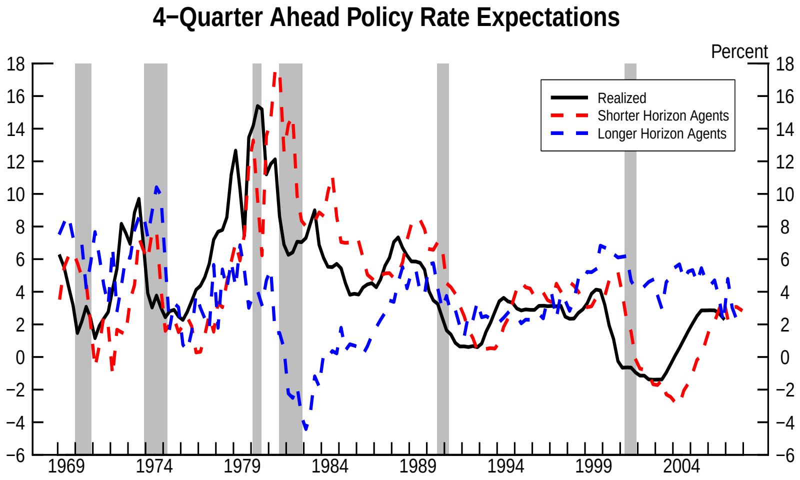


Source: Malmendier and Nagel (QJE 2016).

Inflation Expectations across Planning Horizons



Policy Expectations across Planning Horizons



The Role of Short-Planning Heterogeneity

- How important is the (cross sectional) heterogeneity to explain aggregate dynamics? How do finite-horizon planning "representative agent" models fit aggregate data?

Model	**Log MDD**
Heterogeneous Agents	-716.5
Rep. Agent:	
$K = 0$	-720.9
$K = 1$	-715.9
$K = 2$	-726.2
$K = 3$	-734.7

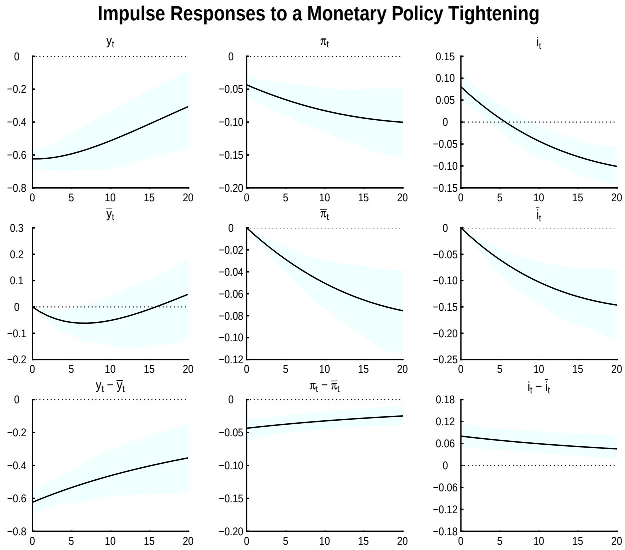
- Does a flexible "distribution function" help in fitting aggregate dynamics?
  - Hard to identify *only* with aggregate data.
  - Important to use the *cross sectional variation over time* on individuals' expectations.

Final Remarks

- The FH model outperforms RE versions of the (hybrid) New Keynesian (with intrinsic persistence elements) as well as other behavioral macro models.
- FH model can be used and extended in several directions:
  - To bring data on individuals' expectations to evaluate the underlying assumptions.
  - To study the heterogeneous implications (on expectations) of alternative MP strategies.
  - To explore the effects of FH planning on firms' investment decisions and capital accumulation.

Thank you

Impulse-Responses: Monetary Policy Tightening



Impulse-Responses: Monetary Policy Tightening